Evaluation of Aerosol Distribution and Optical Depth in GFDL Couple Model

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Abstract. This study evaluates the strength and weakness of aerosol distributions and optical depths used to simulate climate change in the GFDL couple model CM2.1. The concentrations of sulfate, organic carbon, black carbon and dust were simulated using the MOZART aerosol model, while sea-salt concentration is from a previous study by *Haywood et al.* [1999]. These aerosol distributions and pre-calculated specific extinction are used in CM2.1 radiative code to calculate the aerosol optical depth. Our evaluation is based on comparisons, at the global and regional scales, with ground-based and remote sensing observations dating from 1980, as well as previous modeling studies. Overall, the aerosol concentrations are within a factor 2 of the observed values, and have a tendency to be slightly overestimated. Comparison with satellite data shows that the relatively good agreement of global mean optical depth is masked by regional differences of opposite signs. Essentially, the larger than observed optical depth by sulfate compensates the weak contribution of organic and sea salt aerosols. The largest discrepancies are over the North-eastern United States (overestimation of optical depth), biomass burning region and southern oceans (underestimation of optical depth). The best agreement, in terms of reproducing the amplitude and seasonal cycle of optical depth, is obtained in dusty regions. This analysis indicates that the aerosol properties are very sensitive to the humidity, and major improvement could be achieved by taking properly into account their hygroscopic growth along with appropriate modification of optical properties.

1. Introduction

Aerosols scatter and absorb short-wave and long-wave radiation, thereby perturbing the energy budget of the Earth/atmosphere system. Such effects by anthropogenic aerosols exert a direct radiative forcing of climate, but its quantification is difficult due to the large variability of aerosol types and distributions in space and time [*Ramaswamy et al.,* 2001]. Atmospheric measurements provide useful information, but are still not sufficient in understanding quantitatively the spatial distribution of various species, and the role of aerosols in climate. As a result, climate and aerosol models have been the primary instrument used by the Intergovernmental Panel on Climate Change (IPCC) to asses aerosols forcing. But the large variability in model results indicates that significant uncertainties remain, particularly with the role of organic and black carbon aerosols *Penner et al.* [2001]. Most climate models do not prognostic on-line aerosol distributions. Instead, the distributions are simulated off-line by chemical transport models (CTM), which are driven by meteorological fields (either re-analysis or climatology). The off-line distributions are used as an input for the radiative module of climate models. Since the Third Assessment Report (TAR) of the IPCC in 2001, the characterization of aerosols, on regional and global scales, has been improved considerably, with the development of new parameterizations in CTM, launch of new satellite instruments, longer data record of monitoring stations, field campaigns, etc. The new developments allow the models to distinguish among different aerosol types, sources, optical properties, and hygroscopic growth. The evaluation of these developments with available datasets constitutes a crucial part in any assessment. In the framework of the IPCC Fourth Assessment Report (AR4), aerosol distributions have been simulated over the period 1860-2100 with MOZART-2 (Model for Ozone And Re-

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